# METHODS TO IMPROVE ESTABLISHMENT AND GROWTH OF BOTTOMLAND HARDWOOD ARTIFICIAL REGENERATION

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**Abstract**—With ongoing attempts to reforest both cut-over and abandoned agricultural land in the lower Mississippi alluvial plain, it has become evident that there exists a need for an efficient regeneration system that makes biological and economic sense. Also, there is a need to address how to minimize competition from invading weeds, to deter predation by small mammals, and to achieve adequate tree establishment. This study was designed as a randomized complete block experiment with treatments arranged as factors (3 species X 2 levels of protection X 4 weed control treatments) with three replications, to assess efficacy of seedling protection and weed control to improve seedling growth and survival. The study was conducted on a cleared area in the Delta Experimental Forest, Stoneville, MS. Three tree species, Nuttall oak (*Quercus nuttallii* Palmer), green ash (*Fraxinus pennsylvanica* Marsh.), and persimmon (*Diospyros virginia* L.) were planted as 1-0 bareroot seedlings in March 1997. Each treatment plot had 25 seedlings, spaced at 0.75 meters X 0.75 meters. Shelter protection was installed on half of the seedlings. Shelters were 1 meter tall, 15 centimeter diameter plastic tree shelters. Each shelter treatment (with or without shelter) received one of four weed control treatments: mechanical mowing (gas-powered weed cutter), fabric mat (woven, black polypropylene material), chemical herbicide (Oust, sulfometuron-methyl at 210 grams per hectare), or undisturbed (control). Response of shelters and weed control treatments on seedling survival, height and diameter were followed for one growing season. Seedlings in shelters had greater survival (98 percent) than seedlings without shelters (93 percent). For all three species, height growth was significantly greater for sheltered seedlings (43 centimeters) compared to unsheltered seedlings (15 centimeters). For the unsheltered seedlings, fabric mat weed control increased survival relative to chemical weed control. All seedlings had significantly greater height and diameter growth under the fabric mat weed control compared to growth under the other treatments except for unsheltered oak seedlings.

## INTRODUCTION

In the lower Mississippi alluvial plain (LMAP), some land cleared for soybean production is being converted back to bottomland hardwood forests under the Wetland Reserve Program (WRP). Large-scale reforestation of former agricultural lands faces many challenges. Newly planted trees are subjected to harsh site conditions, including heavy clay soils, herbaceous competition, herbivory, drought and flooding. Proper matching of species to soil and site conditions is necessary to successfully establish seedlings. Species commonly used in reforestation under WRP include Nuttall oak (*Quercus nuttallii* Palmer), willow oak (*Quercus phellos* L.), water oak (*Quercus nigra* L.), green ash (*Fraxinus pennsylvanica* Marsh.), cottonwood (*Populus deltoides* Marsh.) and persimmon (*Diospyros virginia* L.). Natural invasion on these sites is usually minimal, as few seed sources exist (Allen 1990). Those species that do invade usually include sweetgum (*Liquidambar styraciflua* L.), green ash and sugarberry (*Celtis laevigata* Willd.). Therefore, the most common reforestation strategy in the LMAP is to introduce hardmast species and rely on wind and water dispersal of light seeded species. With this strategy, fields may or may not be prepared by disking, oaks are established by planting 1-0 bareroot seedlings or direct seeding, and post-planting weed control is typically not used (Haynes and others 1995, Stanturf and others 1998).

Hardwoods have been established successfully on many sites. Krinard and Kennedy (1987) observed 69-97 percent survival rates two years after planting hardwood seedlings on Sharkey clay soil. In their study, Nuttall oak seedling survival averaged 85 percent. Wittwer (1991) recorded a survival rate of 78 percent three years after planting bottomland oaks in eastern Oklahoma. Savage and others (1989) reported a 64 percent survival rate for seedlings on reforested bottomlands in Louisiana, while Schweitzer and others (1997) reported 63 percent survival one year after planting oak seedlings on a former farmed wetland dominated by heavy clay soils. Despite these successes, operational reforestation under WRP has proven difficult. A recent survey of reforested former agricultural lands in west-central Mississippi enrolled in the WRP found that only 23 percent of the land planted with 1-0 bareroot seedlings had at least 100 trees per acre after three growing seasons (Personal communication. 1998. Callie Jo Schweitzer, Research Forest Ecologist, Southern Research Station, P.O. Box 227, Stoneville, MS 38776). The higher survival reported in the studies cited above were on smaller tracts, while the average tract size in the 1992 WRP survey was approximately 210 acres. Nevertheless, Allen (1990) evaluated oak plantations established by USDI Fish & Wildlife Service personnel on refuges in west-central Mississippi. Similar establishment techniques were used on these tracts as the WRP tracts. Seven out of ten stands Allen assessed had over 200 trees per acre.

In addition to animal browsing stress, seedlings must also compete with invading weeds. In areas where climatic

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onditions tend toward droughty, weeds compete for vailable water. A fabric weed barrier, more commonly sed in western states for shelterbelt establishment, may d in short-term moisture retention while mitigating the ffects of herbaceous competition. However, damage from eer and small rodents may still pose a threat to the newly lanted seedlings.

he benefits of tree shelters have been well documented, nostly in cut-over sites in more northern climates. Seedling urvival is increased by minimizing losses from animal amage and by stimulating early height growth that can esult in earlier crown closure (Strobi and Wagner 1995). ree shelters may increase the competitiveness of slower rowing, desirable species on bottomland sites.

Ve investigated the impact of tree shelters and four ifferent weed control treatments on the survival and rowth of three bottomland hardwood species. Our bjective was to evaluate whether weed control, with or vithout tree shelters, could increase survival and growth of ottomland species.

## METHODS

he study was conducted on the Delta Experimental orest, approximately 7.24 kilometers north of Stoneville, MS. The site is dominated by Alligator clay soils (very fine, nontmorillonitic, acid, thermic, Vertic Haplaquepts). Alligator soils are poorly drained and developed in ediments deposited by the Mississippi River. These nontmorillonitic clays have high shrink-swell capacity and re common in bottomland forests and land offered for eforestation in this area. In Delta Experimental Forest, an rea of approximately 1.62 hectares was cleared in 1967 nd has been maintained in grass by bushhogging. The tudy area was surveyed and prepared for planting by ouble disking in the fall of 1996.

n February 1997, three blocks of 24 plots were delineated n the study site. Each treatment plot (4.27 X 4.27 meters) contained 25 planting spots equally spaced at 0.75 X 0.75 neters, and plots were surrounded by a 0.61 meter buffer. Treatment plots were marked with wooden corner stakes nd all planting spots were marked with a flag prior to lanting and weed control treatment. Seedlings were hand lanted using planting shovels on March 12, 1997. Nuttall ak, green ash and persimmon were chosen to study ecause of their compatability on bottomland sites, and heir widespread use in reforestation efforts in the LMAP. The bareroot stock (1-0) used in this experiment was urchased from a local nursery.

Shelter protection was installed on half of the seedlings mmediately after planting. Shelters were 1 meter tall, 15 centimeter diameter, commercially available opaque, plastic ree shelters, each secured with plastic ties attached to a wooden stake. Seedlings also received one of four weed control treatments: mechanical, fabric mat, herbicide or none. Mechanical mowing was implemented manually using a gas-powered weed cutter, applied every other week from March until December 1997. The chemical herbicide Oust sulfometuron-methyl) was applied using a back-pack sprayer on March 21, 1997 at 210 grams per hectare. The fabric mat (woven, black polypropylene material) was placed on plots in 0.91 meter wide strips and secured in place using ground staples. Fabric mat strips overlapped slightly at each seedling row, allowing for the seedling (and seedlings in shelters) to be completely surrounded by mat. No weed control was performed on the control or undisturbed plots after the initial disking for site preparation.

All seedlings were measured immediately after planting and again in January 1998. Height was measured with a meter stick to the nearest centimeter. and diameter was measured with a digital caliper to the nearest millimeter. In July 1997, square meter plots for vegetation sampling were placed in three plots for each weed control treatment. A seedling in the selected plot was randomly selected. and the square meter frame was place next to that seedling. All vegetation was removed, dried and weighed.

Data were analyzed using SAS software (SAS Institute 1988) according to a randomized complete block design with three replications and a factorial treatment arrangement. First-year height and diameter growth were computed by subtracting initial values from final values. Survival rates in decimal fractions were transformed with inverse sine transformation as they covered a wide range of values (Steel and Torrie 1980). Analysis of variance (ANOVA) and Duncan's new multiple range test were used to test for significant differences among treatment means. One-way ANOVA was used to compare survival and growth of seedlings with and without shelters. A three-way ANOVA was used to analyze the effects of weed control, species and blocks on variation in mean seedling growth and survival. Significant differences were reported at the 0.05 percent level.

## RESULTS

### Seedling Survival and Growth

Survival of all species was exceptionally high. Of the total 1800 seedlings planted, only 81 seedlings died. Ash seedlings had significantly higher survival (588/600, 98 percent) than persimmon (550/600, 92 percent), while oak survival (581/600, 96.8 percent) did not differ from that of ash or persimmon. Unsheltered seedlings showed significantly lower survival (841/900, 93 percent) than sheltered seedlings (878/900, 97.6 percent).

Unsheltered ash seedlings had significantly greater survival than persimmon; oak survival was not significantly different than ash or persimmon (Figure 1). Sheltered oak and ash seedlings had significantly greater survival than sheltered persimmon seedlings (Figure 1).

Sheltered seedlings grew significantly taller than seedlings without shelters (height growth with shelter=43.3 centimeters, n=878, without shelter=14.9 centimeters, n=841). However, diameter growth of unsheltered seedlings was greater than diameter growth of sheltered seedlings (diameter growth without shelter=3.9 millimeters, n=841, with shelter=3.3 millimeters, n=878).

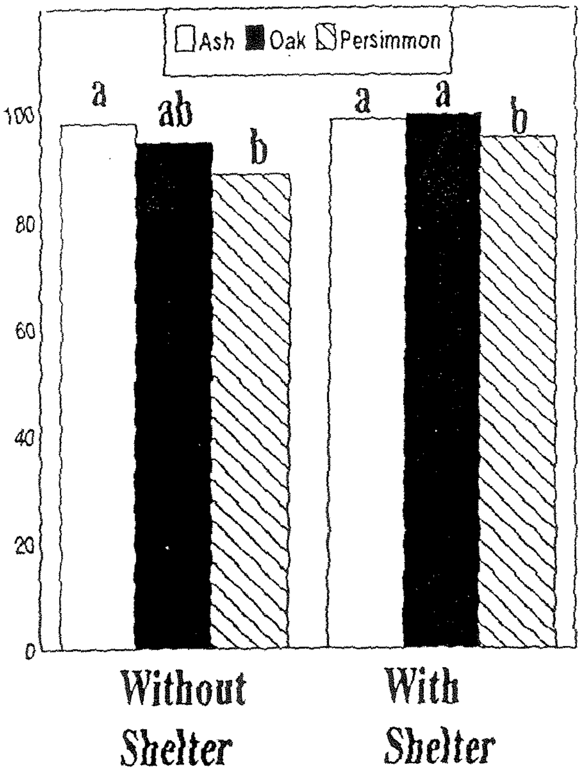


Figure 1—Percent survival comparisons among three bottomland hardwood species with tree shelters and without tree shelters. Means in each shelter grouping followed by different letters are significantly different at the 0.05 level.

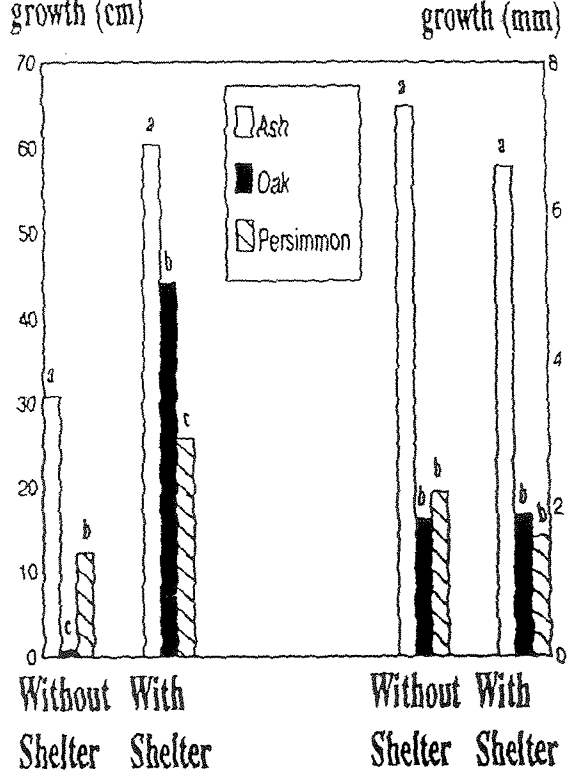


Figure 2—First year height and diameter growth (initial minus final) for three bottomland hardwood species. Means in each shelter grouping followed by different letters are significantly different at the 0.05 level.

Height growth was significantly different among all three unsheltered species, with ash > persimmon > oak (Figure 2). Unsheltered ash seedlings also had significantly greater diameter growth compared to persimmon and oak (Figure 2).

Oak seedlings showed favorable growth in shelters, increasing height growth by 5400 percent. Ash seedlings still grew the tallest, showing 96 percent increase with shelters. For seedlings with shelters, ash diameter growth was significantly greater than oak or persimmon (Figure 2).

However, height growth was significantly greater for sheltered seedlings compared to unsheltered seedlings for each species, under all four weed control treatments. In general, diameter growth was greater for unsheltered seedlings across all weed control treatments. Under the herbicide treatment, unsheltered ash, oak and persimmon seedlings had significantly greater diameter growth than sheltered. Unsheltered ash and persimmon under mechanical weed control also had significantly greater diameter growth than sheltered, and unsheltered persimmon under no weed control had significantly greater diameter growth compared to sheltered persimmon under no weed control.

## Weed Control Treatment

For all seedlings without shelters, those under fabric mat weed control had significantly greater survival than herbicide treatment. Survival of seedlings in the mechanical and no weed control treatments was not significantly different from those in the fabric mat treatment (Figure 3). For any one species without shelters, survival was not significantly different among weed control treatments (Figure 4). Sheltered seedlings under both fabric mat and no weed control treatments had significantly greater surviv than seedlings treated with herbicide (Figure 3). Results were mixed for survival of sheltered seedlings, by species and weed control combinations. Sheltered seedlings in the mechanical weed control treatment had survival rates that were not significant from the other three treatments (Figur 3). Sheltered ash seedlings under herbicide treatment had significantly lower survival than those in mechanical, fabric mat or no weed control treatments (Figure 5). There were no significant differences in survival among the four weed control treatments for sheltered oak seedlings. For sheltere persimmon, fabric mat treatment resulted in significantly greater survival than mechanical or herbicide; survival und no weed control treatment did not vary significantly from a of the other treatments.

Seedlings with shelters and without shelters had significantly greater height and diameter growth under the fabric mat weed control treatment except for unsheltered oak seedlings (Table 1). Unsheltered oaks with no weed control had significantly greater height growth than those seedlings grown with fabric mat as weed control. Height

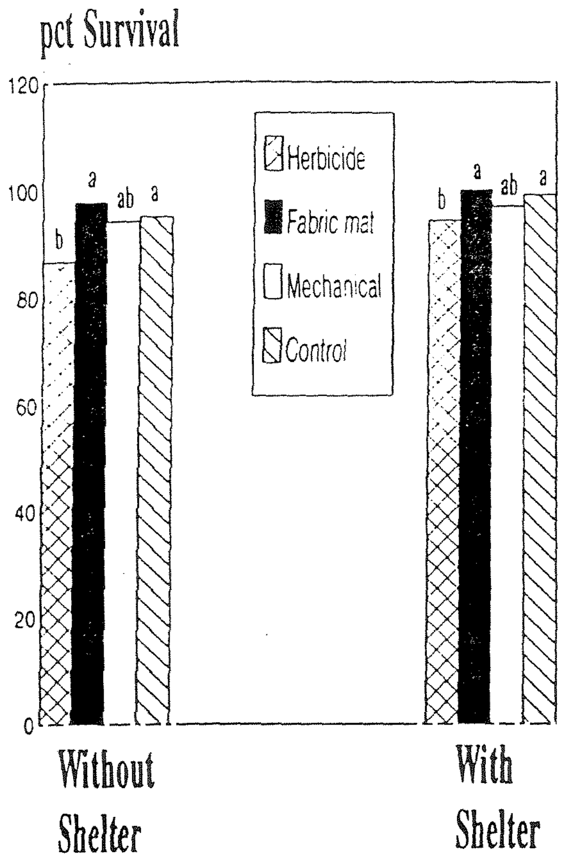


Figure 3—First year survival of all seedlings under four weed control treatments. Means in each shelter grouping followed by different letters are significantly different at the 0.05 level.

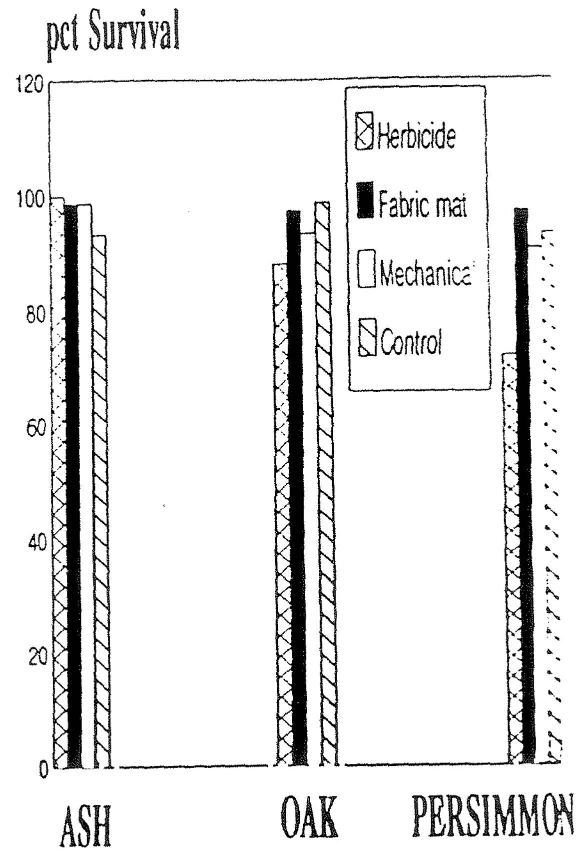


Figure 4—First year survival of three bottomland hardwood species without tree shelters. There were no significant differences in survival means among the four weed control treatments.

Table 1—Results of weed control treatment on height and diameter growth (final - initial) of ash, oak and persimmon seedlings, with and without shelters. Different letters within a row indicate significant difference at the 0.05 level. (Negative values indicate dieback and resprouting)

| | | Herb | Mat | Mech. | None |
|---|---|---|---|---|---|
| | | Cm | | | |
| Height | | | | | |
| Ash | With shelter | 38.6c | 95.3a | 55.4b | 50.3b |
| Ash | W/out shelter | 23.7c | 43.1a | 33.7b | 22.2c |
| Oak | With shelter | 13.4c | 42.1a | 23.5b | 23.9b |
| Oak | W/out shelter | 1.0ab | -1.3b | 0.2ab | 3.4a |
| Per. | With shelter | 24.3c | 59.7a | 46.7b | 44.2b |
| Per. | W/out shelter | 3.5c | 20.3a | 11.3b | 11.5b |
| Diameter | | | | | |
| Ash | With shelter | 3.8c | 12.1a | 4.7b | 5.2b |
| Ash | W/out shelter | 5.9c | 10.9a | 7.3b | 5.4c |
| Oak | With shelter | 1.1c | 3.1a | 1.9b | 1.7b |
| Oak | W/out shelter | 1.8a | 1.7a | 2.1a | 1.8a |
| Per. | With shelter | 1.2b | 3.0a | 1.0b | 1.3b |
| Per. | W/out shelter | 1.7b | 3.3a | 1.8b | 1.9 |

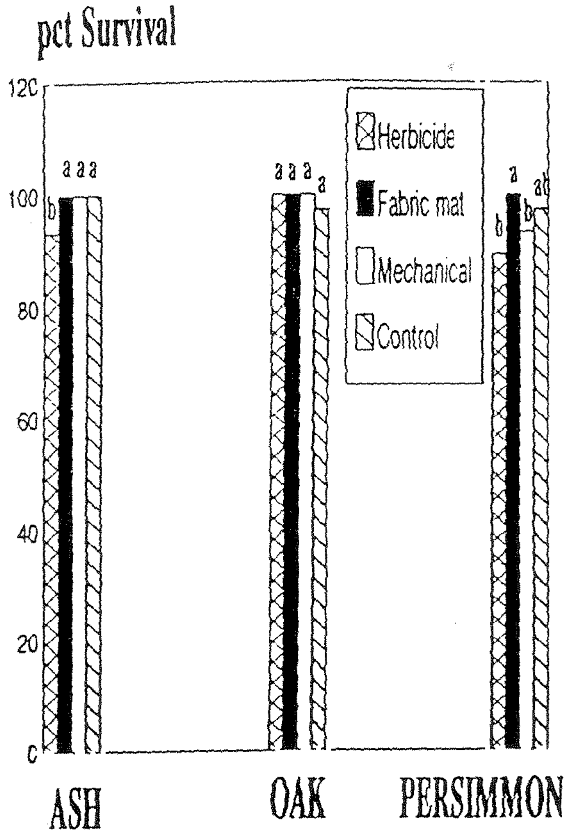


Figure 5—First year survival of three bottomland hardwood species with tree shelters. Means in each species grouping followed by different letters are significantly different at the 0.05 level.

growth for seedlings in the herbicide and mechanical treatments did not differ from either no weed control or fabric mat treatment. Unsheltered oak diameter growth was not different among the four weed control treatments. The herbicide treatment resulted in the smallest height and diameter growth rates, compared to fabric mat, no weed control, and mechanical treatments. This was significant across all species, for seedlings with and without shelters, except for persimmon seedlings with shelters and oak seedlings without shelters. Diameter growth of persimmon seedlings, with shelters, in the herbicide treatment differed significantly only from the fabric mat treatment. Oak seedlings without shelters had the greatest height growth in the no weed control treatment, which was significantly greater than height growth in the fabric mat. There was no difference in diameter growth among the four weed control treatments for oak seedlings without shelters.

## DISCUSSION

Survival of all seedlings was high. Successful establishment may be attributed to proper species selection for the study site, adequate site preparation, and quality control on seedling handling and planting.

### Shelter Effects

Seedlings with shelters had significantly higher survival than seedlings without shelters. In concurrence with literature reports (Tuley 1983, Frearson and Weiss 1987, Lantagne and others 1990) shelters increased survival of the three species we studied.

In addition to improving survival, shelters also enhanced seedling height growth. However, diameter growth was depressed by the shelters. Ponder (1995) reviewed several studies which showed tree shelters accelerated height growth of young trees. These studies have shown that it is not unusual for diameter growth to be less with shelters than without them during the first year or two of growth. Gillespie and other (1996) observed etiolation of sheltered trees. They noted that shifts in light quality or quantity may contribute to this, as well as stems allocating more carbon to height growth and less to caliper or diameter growth with mechanical support coming from the shelter. Lantagne and others (1990) suggested that the modified growing environment created by shelters results in the reallocation of growth from roots, stem diameter and branches to the main stem. The effect of shelters on root growth was not examined in this study. Many of the seedlings in the present study have emerged from the shelters with good apical dominance which should increase their chance of growing into dominant and codominant crown positions.

### Weed Control

The fabric mat used to control weeds had a significant effect on the survival and growth of the seedlings. In reforestation, mulch mats appear to suppress competing vegetation primarily by blocking light necessary for photosynthesis, and to a lesser extent, by mechanically impeding growth (Clarkson and Frazier 1957). To control weeds effectively, mulches must be applied early, remain intact, and be large enough. The fabric mulch mat used in this study was applied prior to weed establishment on a disked field. We did encounter some difficulties installing the mat. Ground staples were used to secure the corners, and additional staples had to be placed 0.5 m apart to hold the mat in place. In addition to the staples, we also placed clay pots on all the corners to aid in keeping the mat from blowing around. Installment was difficult in the heavy clay soil, as the mat became stuck with mud before it could be spread out evenly. The cost of the mat may also prohibit its use in large-scale reforestation efforts.

The fabric mat treatments had significantly lower weed biomass compared to the other weed control treatments (Table 2). Although the herbicide treatment reduced weeds compared to no weed control treatment, height and diameters of all seedlings studied were reduced compared to the other three weed control treatments. Kennedy (1981) used disking, mowing and no weed control on several bottomland species to examine survival and growth under different cultural treatments. After four growing seasons, he found that there was no difference in seedling survival, height or diameter for seedlings that were mowed versus those in the control. Disking did improve survival and growth. Kennedy (1981) concluded that competition still exists whether weeds are allowed to grow and cut back by mowing or to grow continuously as in the control, therefore mowing was not an acceptable substitute for disking.

Table 2—Total weed biomass collected from three plots in each weed control treatment. Different letters within weight column indicates significant difference at 0.05

| Weed control treatment | Total weight | n | Dominant vegetation |
|---|---|---|---|
| | *G* | | |
| None | 605.38a | 9 | Bundle weed[a], vines, grass |
| Herb | 404.42b | 9 | Bundle weed |
| Mech. | 298.32b | 9 | Grass |
| Mat | 167.83c | 9 | Grass, bundle weed |

Means in each shelter grouping followed by different letters are significantly different at the 0.05 level.
[a] Bundle weed (*Desmanthus illinoensis* Michaux).

## CONCLUSIONS

The results of this study indicate that a potential exists for the use of tree shelters in bottomland hardwood reforestation. Herbivory was not a major stress in this study, although browsing damage has been reported by others who have artificially reforested in this area. Therefore, protection benefits of tree shelters need to be more thoroughly tested under heavy animal pressure. The accelerated height growth of sheltered seedlings after one year compared to the unsheltered seedlings showed promise that those seedlings will rise above the competing vegetation and herbivores. This increase in height growth may also be beneficial in areas that receive late season flooding, common on bottomland sites. Seedlings that are above the flood water levels have a greater chance of survival.

It is premature to prescribe a method for regenerating bottomland hardwood species based on the first growing season. Based on first growing season results, however, data from this study show that an application of sulfometuron-methyl herbicide reduced the amount of competing vegetation, but appeared to suppress seedling survival and growth. Best survival and growth, and the lowest weed invasion, was found with the fabric mat. Although both the shelters and the fabric mat gave positive survival and growth results, cost may be a prohibitive factor in their large-scale use.

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## REFERENCES

**Allen, J.A.** 1990. Establishment and growth of bottomland oak plantations on the Yazoo National Wildlife Refuge Complex. Southern Journal of Applied Forestry. 14(4): 206-210.

**Clarkson, V.A.; Frazier, W.A.** 1957. Plastic mulches for horticultural crops. Station Bull. 562. Corvallis, OR: Oregon State College, Agriculture Experiment Station. 12 p.

**Frearson, K; Weiss, N.D.** 1987. Improved growth rates within tree shelters. Quarterly Journal of Forestry. 81(3): 184-187.

**Gillespie, A.R.; Rathfon, R.; Myers, R.K.** 1996. Rehabilitating a young northern red oak planting with tree shelters. Northern Journal of Applied Forestry. 13(1): 24-39.

**Haynes, R.J.; Bridges, R.J.; Gard, S.W. [and others].** 1995. Bottomland forest reestablishment efforts of the U.S. Fish & Wildlife Service: Southeast Region. In: Fischenich, J.C.; Lloyd, C.W.; Palermo, M.R., eds. Proceedings national wetlands engineering workshop. Tech. Rep. WPR-RE-8. Vicksburg, MS: Waterways Experiment Station: 322-334.

**Kennedy, H.E.** 1981. Foliar nutrient concentrations and hardwood growth influenced by cultural treatments. Plant and Soil. 63: 307-316.

**Krinard, R.M.; Kennedy, H.E.** 1987. Fifteen-year growth of six planted hardwood species on Sharkey clay soil. For. Res. Note SO-336. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 4 p.

**Lantagne, D.O.; Ramm, C.W.; Dickman, D.F.** 1990. Tree shelters increase heights of planted oaks in a Michigan clearcut. Northern Journal of Applied Forestry. 7: 24-26.

**Ponder, F.** 1995. Shoot and root growth of northern red oak planted in forest openings and protected by treeshelters. Northern Journal of Applied Forestry. 12(1): 36-42.

**SAS Institute.** 1988. PC-SAS user's guide. Statistics. Version 6.04 ed. Cary, NC: SAS Institute.

**Savage, L.; Pritchett, D.W.; DePoe, C.E.** 1989. Reforestation of a cleared bottomland hardwood area in northeast Louisiana. Restoration and Management Notes. 7(2): 88.

**Schweitzer, C.J.; Stanturf, J.A.; Shepard, J.P. [and others].** 1997. Large-scale comparison of reforestation techniques common to the Lower Mississippi Alluvial Valley: first-year results. In: Pallardy, S.G.; Cecich, R.A.; Garrett, H.G.; Johnson, R.S., eds. Proceedings, 11th central hardwood forest conference. Gen. Tech. Rep. NC-188. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 410 p.

**Stanturf, J.A.; Schweitzer, C.J.; Gardiner, E.S.** 1998. Afforestation of marginal agricultural land in the Lower Mississippi River Alluvial Valley, U.S.A. Silva Fennica. 32(2): 281-297.

**Steel, R.G.D.; Torrie, J.H.** 1980. Principles and procedures of statistics: a biometrical approach. New York: McGraw-Hill. 633 p.

**Strobi, S.; Wagner, R.G.** 1995. Early results with translucent tree shelters in southern Ontario. In: Brissette, J.C., ed. Proceedings of the tree shelter conference; 1995 June 20-22; Harrisburg, PA. Gen. Tech. Rep. NE-122. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 13-18.

**Tuley, G.** 1983. Shelters improve the growth of young trees in forest. Quarterly Journal of Forestry. 77: 77-87.

**Wittwer, R.F.** 1991. Direct-seeding of bottomland oaks in Oklahoma. Southern Journal of Applied Forestry. 15(1): 17-22.

**Stringer, Jeffrey W.; Loftis, David L., eds.** 1999. *Proceedings, 12th Central* Hardwood Forest Conference; 1999 February 28, March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p.

There were 32 oral presentations, 11 abstracts, and 22 poster presentations presented at the 12th Central Hardwood Forest Conference. Presentation topics included wildlife management, nutrient dynamics, stand structure, reforestation/reclamation, timber harvesting, modeling and inventory, silviculture, disturbance effects, and genetics/tree improvement.

**Keywords:** Air pollution, forest ecology, forest economics, forest health, forest management, harvesting, oak-hickory, reclamation, reforestation, silviculture, stand dynamics, timber harvesting, tree physiology.